

## **CANDOS MISSION**

The successful demonstration of the Low Power Transceiver (LPT) was the primary objective of the CANDOS mission, which flew as a HitchHiker payload on STS-107. The LPT aspects of the mission are reported elsewhere. The secondary objective of the CANDOS mission was to perform Internet-in-space experiments and demonstrations, the results of which are summarized here.

During the CANDOS flight, practically all of the typical mission operations scenarios were demonstrated using the CANDOS communications system with standard Internet protocols and technologies. The on-board computer (X86 class CPU) ran an off-the-shelf distribution of Red Hat Linux with an unmodified standard Internet Protocol (IP) stack. The simple addition of an off-the-shelf commercial router enabled the NASA ground stations (WSGT, STGT, Wallops, MILA, and Dryden (for range safety experiments) to provide full support for CANDOS.

The Internet-in-space experiments and demonstrations were devised and conducted by the Operating Missions as Nodes on the Internet (OMNI) Project managed by James Rash (Code 588) and supported by a team of engineers from Computer Sciences Corporation (<http://ipinspace.gsfc.nasa.gov>). The CANDOS Project Manager is David Israel (Code 567). NASA/Glenn provided the routers at the ground stations.

The full range of experiments and demonstrations successfully conducted during the flight helps establish the applicability of Internet Protocol communications approaches in future space missions.

Specifically, the CANDOS flight demonstrations included the following spacecraft operations conducted from secure consoles in the POCC:

- Automated establishment of end-to-end connectivity through both TDRSS and ground stations using the mobile IP protocol with authenticated access control from the POCC located on GSFC's closed IONet
- Commanding
  - blind commanding using the User Datagram Protocol (UDP)
  - reliable upload of stored command files using the Multicast Dissemination Protocol (MDP) and the secure copy protocol (SCP)
  - secure, encrypted commanding and data transfers using the secure shell protocol (ssh) and SCP
- File delivery
  - reliable upload of software update files using MDP
  - reliable file transfers over both two-way and one-way communications links using MDP
  - reliable return of science data files using MDP, the File Transfer Protocol (FTP), and SCP
  - reliable file delivery from the spacecraft to a console hundreds of miles from the POCC using SCP

- reliable file delivery spanning TDRSS and ground station handovers using MDP, FTP, and SCP
- Telemetry
  - real-time telemetry (status of LPT) using UDP status packets over two-way and one-way links
  - immediate delivery of spacecraft status using UDP over a one-way path through a firewall to a remote location
  - telemetry to multiple destinations determined and controlled by the onboard processor
  - simultaneous control of spacecraft operations using ssh from multiple consoles including a console hundreds of miles from the POCC
  - automated spacecraft operations using the cron scheduling command
  - on-board clock synchronization with the Network Time Protocol (NTP)

The above demonstrations were carried out securely in conformance with an approved security plan. Both TDRSS and ground stations were used for the demonstrations.

The test data from all IP-in-space experiments conducted during the CANDOS mission were downloaded from the spacecraft during the flight and are being analyzed for publication and presentation as technical papers at upcoming conferences such as GSAW 2003, ITC 2003, and SmallSat.

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